

OFFSHORE MEMBRANE ENCLOSURES FOR GROWING ALGAE (OMEGA) SYSTEM FOR BIOFUEL PRODUCTION, WASTEWATER TREATMENT, AND CO₂ SEQUESTRATION

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SUMMARY: We are developing Offshore Membrane Enclosures for Growing Algae (OMEGA). OMEGAs are closed photo-bioreactors constructed of flexible, inexpensive, and durable plastic with small sections of semi-permeable membranes for gas exchange and forward osmosis (FO). Each OMEGA module is filled with municipal wastewater and provided with CO₂ from coastal CO₂ sources. The OMEGA modules float just below the surface, and the surrounding seawater provides structural support, temperature control, and mixing for the freshwater algae cultures inside. The salinity gradient from inside to outside drives forward osmosis through the patches of FO membranes. This concentrates nutrients in the wastewater, which enhances algal growth, and slowly dewateres the algae, which facilitates harvesting. The concentrated algal biomass is harvested for producing biofuels and fertilizer. OMEGA system cleans the wastewater released into the surrounding coastal waters and functions as a carbon sequestration system.

Keywords: freshwater microalgae, biofuel, offshore membrane enclosure, wastewater treatment, photo-bioreactor

INTRODUCTION

It is well known that microalgae can provide a significant amount of carbon-neutral, sustainable biofuels when they are grown in large quantities under economical conditions^[1]. To date, there are no algae cultivation methods on land that meet these requirements of scale and economics for biofuels. To try to meet these requirements, we are proposing to explore the possibilities of growing algae in offshore membrane enclosures in the ocean. This system of offshore membrane enclosures for growing algae (OMEGA) will consist of lightweight, flexible, closed photo-bioreactors constructed of inexpensive plastic with small sections of semi-permeable membranes for gas exchange and dewatering. They will be filled with nutrient-rich primary or secondary treated wastewater from municipal sewage treatment facilities and the sealed enclosures will be inoculated with lipid-producing freshwater algae (mono-cultures or communities). Strains of algae will be cultivated that are able to thrive under local conditions and out-compete weed species in the wastewater. Our goal is to demonstrate the feasibility of using OMEGA on a reasonable pilot scale, to show that these plastic enclosures can be deployed, filled with effluent, inoculated with algae, and can grow algae to high concentrations, and then be harvested, reused, and ultimately recycled. Through our demonstration project we will evaluate if such an OMEGA system can be used to economically produce biofuels.

CONCEPT OF OMEGA

The OMEGA module is a floating clear plastic enclosure with external (FO) membranes, access and pressure-relief valves and internal CO₂ bladders, which diffuse CO₂ into the algae culture and at the same time provide flotation for the system. The algae culture grows in the clear plastic enclosure using sunlight, nutrients from the wastewater, and both the nutrients and culture are concentrated by the FO membranes during the 10-14 days of cultivation. The culture is harvested using pumps at the end of the growth cycle. OMEGA modules are refilled with wastewater and recharged with CO₂. The residual algae in the modules act as the inoculum for the next culture cycle.



Figure. 1 Schematic representation of OMEGA system

RESULTS

Our results to date in the laboratory indicate that FO and gas exchange membranes will function for >20 algal growth cycles and are expected to exceed 40 to 50 cycles, or greater than one year in operation. This remains to be tested under field conditions, but we believe we can develop protocols to allow these membranes to function for well over one year. By designing the OMEGA modules so the membranes can be replaced, we expect to use the plastic modules for at least two years.

In our past laboratory experiments with *Chlorella vulgaris*, a freshwater alga known to produce oil and a potential species for field experiments, we have grown *C. vulgaris* in a small OMEGA module (20cm x 20cm x 1, 2, or 3 cm) made of clear polyurethane with or without forward osmosis membranes. The dewatering rate of the algal culture was up to 85% (range of 65-85%) over the 4-hour period (Figure 2).



Figure 2. Dewatering of algae culture in OMEGA module with FO membrane

The growth conditions included using primary or secondary wastewater from the Sunnyvale wastewater treatment facility or using a standard laboratory medium for growing algae (BG-11). We used constant light (177 ft candles), constant stirring, and added CO₂. The cultures grown in OMEGA modules 2 or 3 cm deep did not exceed 2 g/liter dry wt, indicating the cultures were light limited. Cultures grown in 1 cm deep OMEGA modules achieved 6 g/L (data not shown), which is agreement with previously published work studying the effects of light limitations^[2].

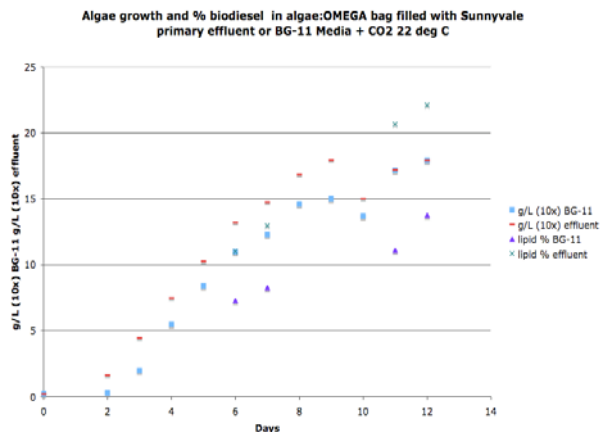


Figure 3. Algal growth and % biodiesel results in simulated ocean with both primary wastewater and laboratory media. Note: biomass concentration scaled up 10x to correspond to % biodiesel.

DISCUSSION

The Algae OMEGA technology is intended to be a triple-payback system. In addition to producing biofuels, fertilizer, and other valued products, the OMEGA system functions as a wastewater treatment facility, and as a carbon sequestration system. In other words, OMEGA is one part product-oriented and two parts environment-oriented. Even the products are environmentally friendly. The biofuel produced is carbon-neutral or carbon-negative and the fertilizer is made from nutrients recovered from municipal wastewater, such as phosphorus, nitrate, and ammonia, which are currently lost to the oceans. The recovery of these nutrients will both decrease the growth of dead-zones in coastal regions as well as provide valuable fertilizers for agricultural community.

References

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